II.6 Small-Scale Low-Cost Solid Oxide Fuel Cell Power Systems

Objective

- To develop a commercially viable 5-10 kWe solid oxide fuel cell power generation system that achieves a factory cost goal of $400 per kWe.

Accomplishments

- Demonstrated 90% higher power density (W/cm^2) and more than 2.5 times more power per cell for Delta9 cells compared to tubular cells.
- Demonstrated over 3,000 hours voltage stability for Delta9 cells at 1,000°C and 80% fuel utilization.
- Developed an alternate cathode composition with 10% lower cost and 50% higher conductivity (at 900°C) than present cathode composition.
- Completed assembly of a prototype system.

Introduction

The objective of this project is to develop a standard high-performance, low-cost SOFC system that can be manufactured in high volume for application in a number of different end uses, including residential and as auxiliary power units in commercial and military transportation applications. The proposed project is a 10-year, three-phase project with prototype SOFC systems being tested at the end of every phase, the first of which will be completed this year. Performance and cost improvements made during each phase will be incorporated in each prototype, and products based on each prototype will be made ready for market entry as they become available.

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Approach

We have identified key technical issues that must be resolved to achieve low-cost commercial SOFC systems. We will focus on cost reductions and performance improvements to transform today's SOFC technology into one suitable for low-cost mass production of small systems for multi-market applications. The key advances identified are:

- Improved cell performance through design and materials innovations to more than double the power and thus reduce cost/kWe
- On-cell reformation of natural gas fuel to eliminate high-cost internal reformer components
- Use of low-cost insulation and containment vessels by lowering the system operating temperature
- Use of net shape cast components to reduce machining costs
- Simplification of stack and balance of plant (BOP) designs to lower parts count
- High efficiency (95%) power conditioning systems to improve overall system electrical efficiency

In addition to the key advances noted above, adoption of more automated, mass production techniques for cell, module and BOP manufacturing will ensure overall SOFC system cost effectiveness.

Results

Prior to the start of the project, it was recognized that Siemens' seal-less tubular cell design would not be able to meet the cost and performance targets of the project. A need to develop a cell with higher power density and compact design was identified. A new design that combined the seal-less feature and a flattened cathode with integral ribs was chosen. This new design, referred to as a high power density (HPD) cell, has a closed end similar to the tubular design. The ribs reduce the current path length by acting as bridges for current flow. The ribs also form air channels that eliminate the need for air feed tubes. This cell design, due to its shorter current path, has lower cell resistance and hence higher power output than tubular cells. A variation of the HPD design, Delta9, has a corrugated surface which significantly increases the active area of the cell, yielding higher power per cell. Figure 1 shows the tubular and Delta9 cells.

During FY 2006, Delta9 cells produced 90% higher power density and more than 2.5 times more power per cell than tubular cells at 0.65 V, 900ºC operating

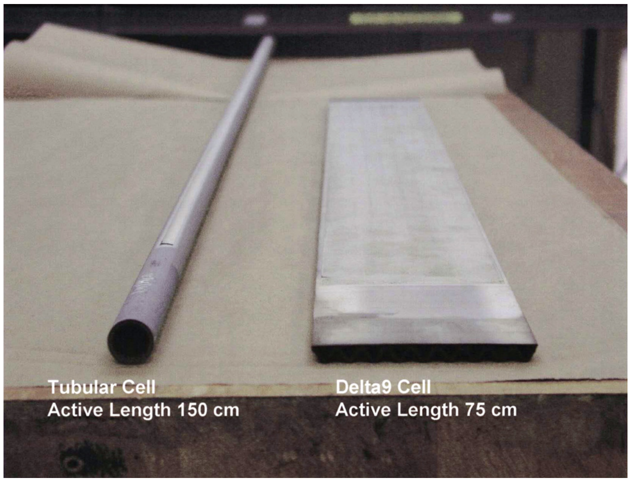

FIGURE 1. Tubular and Delta9 Cells

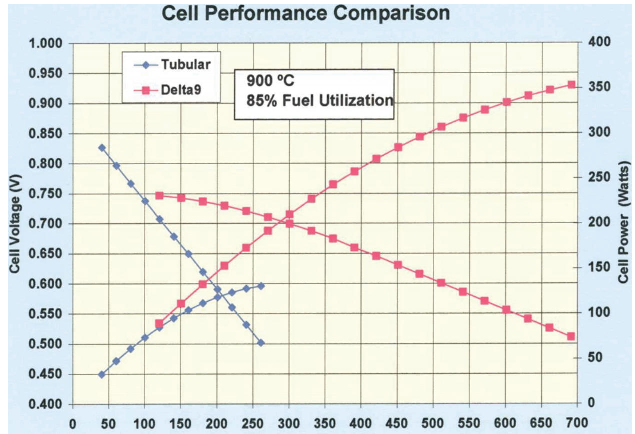

FIGURE 3. Voltage versus Current Comparison for Tubular and Delta9 Cell

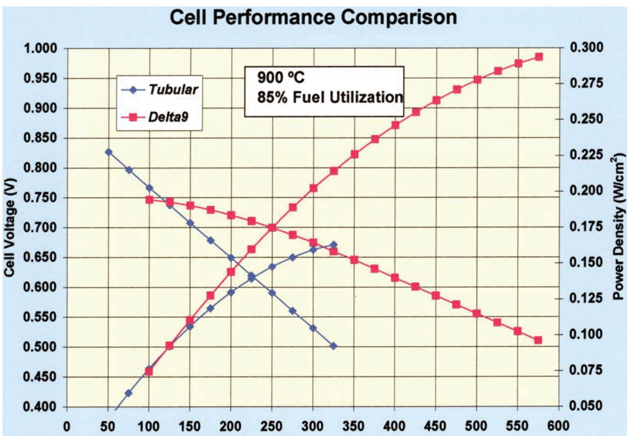

FIGURE 2. Voltage versus Current Density Comparison for Tubular and Delta9 Cell

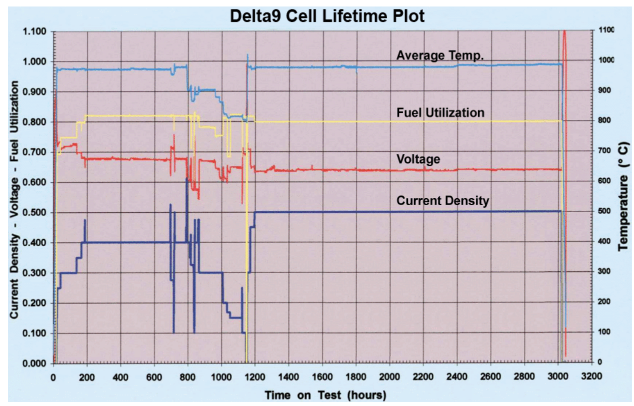

FIGURE 4. Voltage versus Time Plot for Delta9 Cell

temperature and 85% fuel utilization. Figure 2 shows the voltage versus current density comparison for tubular and Delta9 cells. Figure 3 shows the voltage versus current for tubular and Delta9 cells.

Delta9 cells were fabricated and tested for voltage stability. Figure 4 shows voltage stability of a Delta9 cell over approximately 3,000 hours of operation at 1,000°C and 80% fuel utilization. There was no noticeable voltage degradation for the Delta9 cell when tested at conditions described above. This exceeds SECA program goals for voltage stability.

Computational modeling of thermal and electrical fields initiated in FY 2005 to optimize the cell and stack design for maximum power and mechanical stability from thermal stresses during stack operation continued during FY 2006. Efforts were also directed towards the development of cell-to-cell connections to bundle cells.

An alternative cathode composition was developed and evaluated through cell testing. Initial results show acceptable cell properties and performance, with material costs approximately 10% lower than that of present compositions. This is very significant because over 95% of the cell material is the cathode.

Assembly of a prototype system for residential applications was completed. Figure 5 shows the flow schematics of this system. The primary objective of the system is to demonstrate operation of HPD cells in a generator environment. The system will run on natural gas; fuel reformation will be internal to the cell stack.

Conclusions and Future Directions

- Fabrication processes for Delta9 cells were established, and electrical testing showed significant improvement in power density over tubular cells.
- Developed a new low-cost cathode composition.
- Constructed prototype system to run on internally reformed natural gas.
- We will optimize cell and stack design for maximum power and reliability.

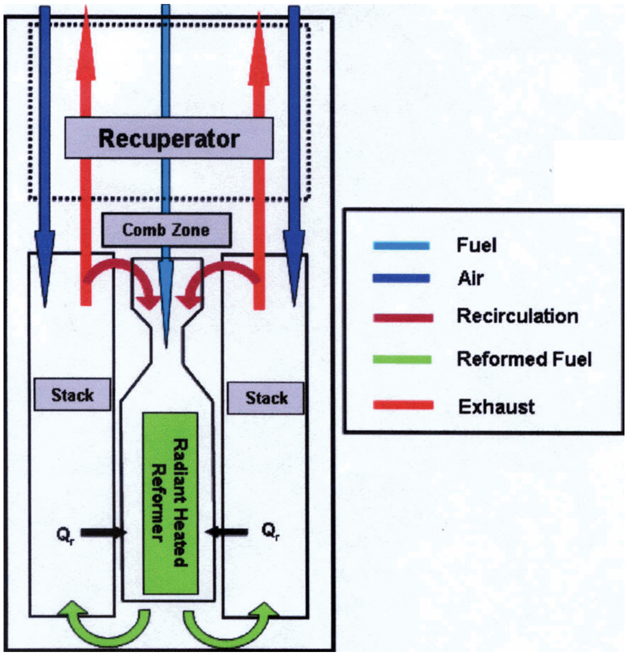

FIGURE 5. Flow Schematics of Prototype Residential System

- We will evaluate and develop automated mass production processes for cell, module and BOP components.

FY 2006 Publications/Presentations

1. S. D. Vora, "Development of High Power Density Seal-less SOFCs", Presented at the 2005 Fuel Cell Seminar, November 14-18, 2005, Palm Springs, CA.

2. G. Zhang, "New Cathode and Interlayer Materials Development at Siemens Power Generation", Presented at 209th Electrochemical Society Meeting, May 7-12, 2006, Denver, CO.

3. A. Iyengar, G. DiGiuseppe, N.A. Desai, S. D. Vora and L. A. Shockling, "Computational Modeling of Thermal and Electrical Fields of a High Power Density Solid Oxide Fuel Cell", Presented at the ASME Fuel Cell Conference 2006, June 19-21, Irvine, CA.

4. K. Huang, "Cell Power Enhancement via Materials Selection", Proceedings of the 7th European Fuel Cell Forum, July 4-7, 2006, Lucerne, Switzerland.